



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

Langley

JAN 27 1975

REPLY TO  
ATTN OF: GP

TO: KSI/Scientific & Technical Information Division  
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General  
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.

: 3,859,736

Government or  
Corporate Employee

: U.S. Government

Supplementary Corporate  
Source (if applicable)

: [Signature]

NASA Patent Case No.

: LAR-10,276-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

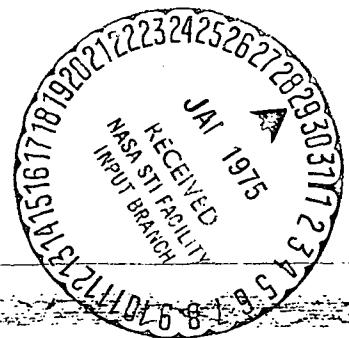
YES ☐

NO ☒

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner

Bonnie L. Woerner  
Enclosure



(NASA-Case-LAR-10276-1) KINESTHETIC CONTROL  
SIMULATOR Patent (NASA) 7 p CSCL 14B

N75-15662

09/09

Unclas  
07144

[54] KINESTHETIC CONTROL SIMULATOR

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[22] Filed: Apr. 20, 1970

[21] Appl. No.: 29,979

[52] U.S. Cl. .... 35/12 C, 272/1 R, 272/57 A

[51] Int. Cl. .... G09b 9/08

[58] Field of Search ..... 35/12 R, 12 C, 12 E, 12 P;  
272/1 B, 1 C, 1 R, 33 R, 33 A, 57 A, 60

[56] References Cited  
UNITED STATES PATENTS

1,565,484	12/1925	McWhirter	272/57 A
1,979,844	11/1934	Rouenville	272/1 R
3,024,021	3/1962	Coplin et al.	272/57 A
3,281,963	11/1966	Johnson	35/12 C

3,449,843	6/1969	Richter et al.	35/12 P
3,477,713	11/1969	Cudmore	272/1 R X

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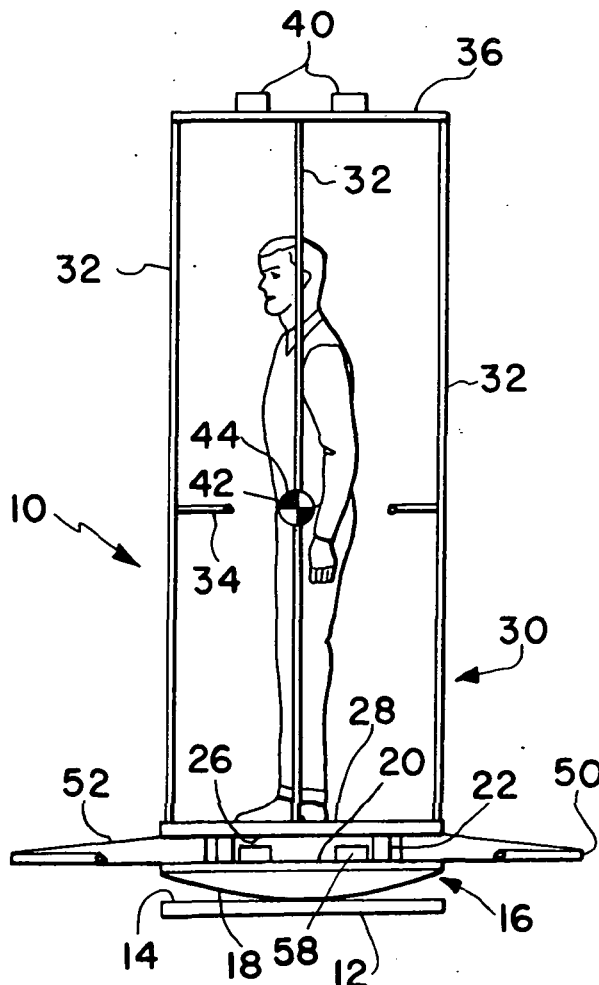
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[57] ABSTRACT

A kinesthetic control simulator having a flat base upon which rests a support structure having a lower spherical surface for rotation on the base plate with columns which support a platform above the support structure at a desired location with respect to the center of curvature of the spherical surface. A handrail is at approximately the elevation of the hips of the operator above the platform with a ring attached to the support structure which may be used to limit the angle of tilt. Five degree freedom-of-motion can be obtained by utilizing an air pad structure for support of the control simulator.

3 Claims, 6 Drawing Figures



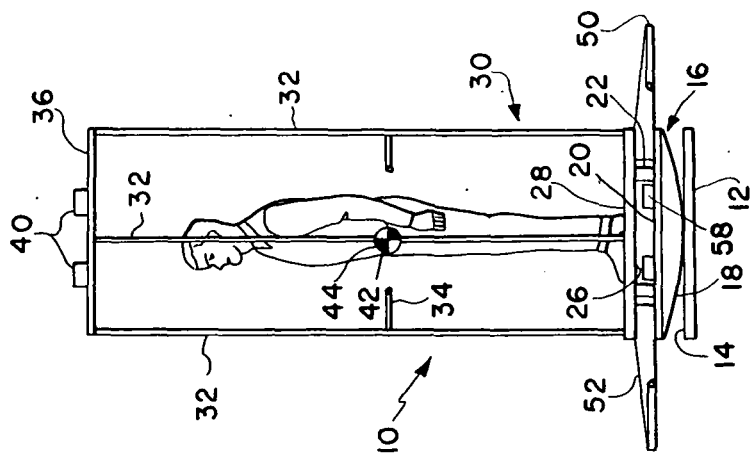


FIG. 1

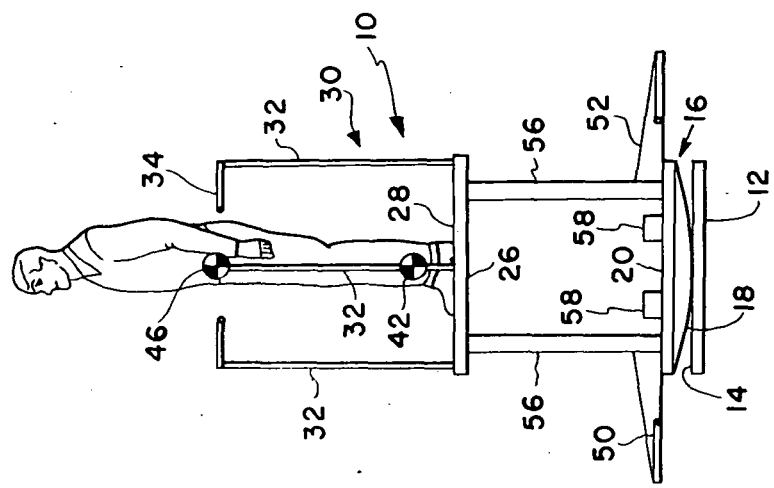


FIG. 2

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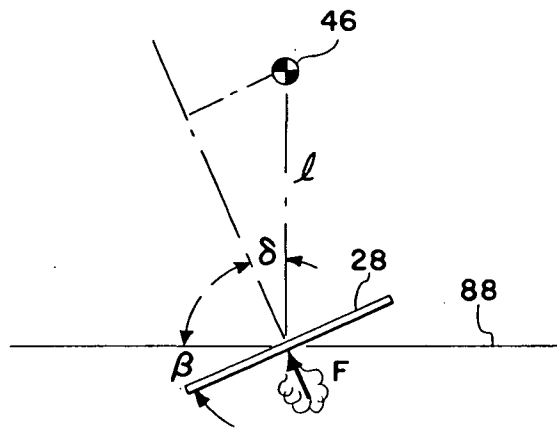


FIG. 3

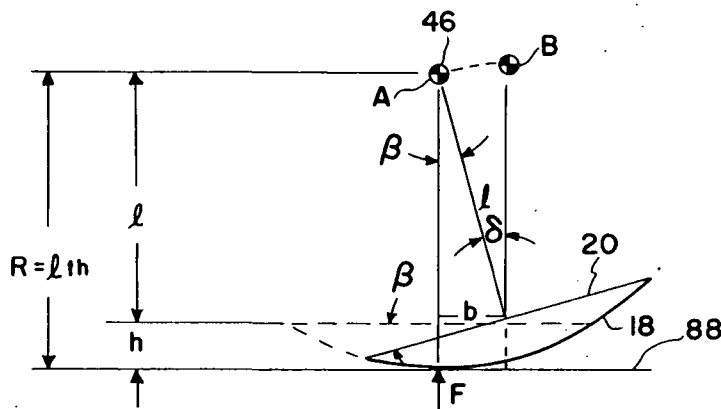


FIG. 4

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FIG. 5

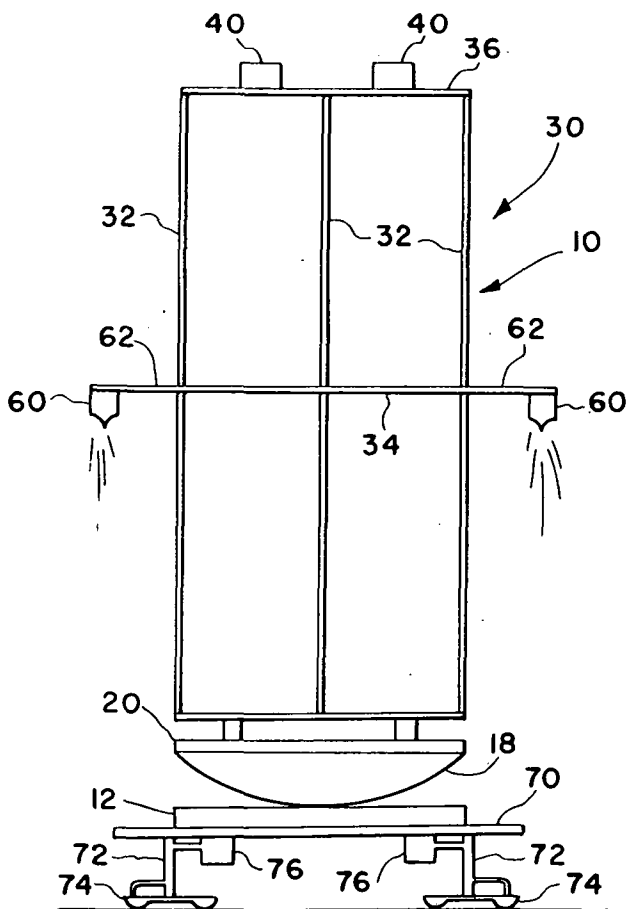
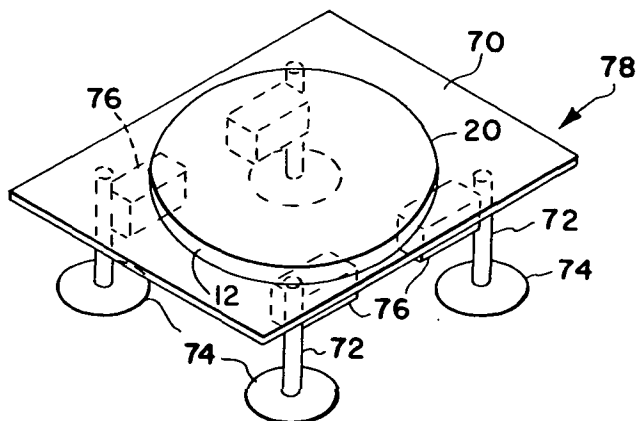


FIG. 6



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## KINESTHETIC CONTROL SIMULATOR

## ORIGIN OF THE INVENTION

The invention described herein was made by employees of the U.S. Government and may be manufactured and used by or for the Government for governmental purposes without the payment of royalties thereon or therefor.

## BACKGROUND OF THE INVENTION

This invention relates generally to simulators and more particularly to a kinesthetic control simulator for experience in multiple degree freedom of movement.

Previous devices utilized a balancing platform free to rotate about one horizontal axis. Rotation of the platform was used as input to an automatic servo system to drive the platform along a horizontal track perpendicular to the axis of platform rotation. This device failed to operate satisfactorily in that it did not simulate the attitude control of a flying platform because rotation was restricted to motion about one axis. Moreover, the platform size greatly restricted the operator's feet and the control "feel" of the device did not correspond to previous experiences with actual flying platforms.

It has also been known to utilize devices on which the operator was firmly attached by straps or other means and which used, for example, an air cushion to provide a degree of weightless simulation and the operator with a feel for three-dimensional movement. These devices obviously have the disadvantage of being large and cumbersome and requiring expensive construction, as well as critical operating procedures. It has also been known to utilize mechanisms having air cylinders to provide an air cushion for suspension of the vehicle above the floor surface with the operator standing in a spherical portion which is mounted for free rotation. This construction would permit three degrees of freedom; however, it fails to give the operator a true indication of feel at least partially caused by the requirement for manual control by the operator of a reaction gun. Furthermore, the operation of the device is limited through the amount of air that can be stored within the chamber on the vehicle or the vehicle movement limited by some type of conduit for conveying pneumatic pressure for the air cushion.

Wherever kinesthetic control is used herein the term refers to control by the sense whose end organs lie in the muscle, tendons and joints and which are stimulated by bodily movement and tensions; also known as the muscle means. Kinesthetic alternatively is the type of sensory experience derived from the sense having its end organs lying in the muscles, tendons and joints.

It is an object of the instant invention to provide a large radius, spherical surface for rotational control for attitude simulation of a flying platform.

Another object of this invention is to provide an inexpensive readily available device for simulation of kinesthetic control such as would be used in operating vehicles similar to a lunar flying platform.

Another object of the instant invention is to provide a simulator which can be utilized for studying engineering parameters such as inertia, platform size and control location needed for the design of both the surface-to-surface and the surface-to-orbit type vehicles.

Still another object of the instant invention is to provide a safe, simple, inexpensive, yet accurate, simulator for astronaut training.

A still further object of this invention is to provide a spherical surface for rotation upon a base with a stand-on platform for support of the operator and which is supported above the spherical surface to provide simulation of a flying platform.

Yet another object of the instant invention is to provide a kinesthetic control simulator having five degrees freedom of motion effected by utilizing an air pad structure for support of a control simulator wherein columns connect a stand-on platform to a spherical lower surface.

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily apparent as the same becomes better understood by reference to the following description, when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a side elevational view of the instant invention;

FIG. 2 is a side elevational view of an alternative embodiment of the invention;

FIG. 3 is a diagrammatic view for analysis of a rocket powered device similar to the instant invention;

FIG. 4 is a diagrammatic view for analysis of the simulation device of the instant invention;

FIG. 5 is a side elevational view, with portions omitted for clarity, of a modified embodiment of the instant invention; and

FIG. 6 shows an isometric view of an air support system for the control simulator of the instant invention.

Referring now to the drawings and more particularly to FIGS. 1 and 2 wherein the instant inventive simulator 10 is shown as including base 12 having upper surface 14 on which rests the lower spherical surface 18 of support 16 that also includes upper surface 20. Columns 22, FIG. 1, are rigidly secured to surface 26 of platform 28. Platform 28 is the stand-on support for the operator of the instant inventive simulator 10.

Framework 30 is rigidly secured to platform 28 and extends upwardly therefrom utilizing vertical frame 32. Handrail 34 extends around the operator substantially parallel to platform 28 and at approximately the elevation of the hips of the operator. Horizontal top frame 36 secures the upper ends of vertical frame 32 and supports counterweights 40 for a purpose to be more fully understood hereinafter. As an option in FIG. 1 embodiment, counterweights 58 may also be added to support 16, the purpose of which will be explained subsequently.

Center-of-curvature 42 of spherical surface 18 is located in FIG. 1 at approximately the elevation of the waist of the operator. Center-of-gravity 44 is established by the combined mass of the operator and simulator 10 structure and should substantially coincide with center-of-curvature 42 for zero stability.

Tilt ring 50 permits a maximum degree of rotation of simulator 10 and is attached to platform 28 and support 16 by braces 52.

The alternative embodiment of the invention shown in FIG. 2 is substantially identical to that shown in FIG. 1 with the exception that platform 28 is spaced a greater distance from flat upper surface 20 of support 16 by elongated columns 56. It is to be noted that columns 56 could be of a telescopic construction for use

in the embodiment of both FIGS. 2 and 1, as well as any configuration therebetween.

A lock pin inserted into coinciding apertures or a similar locking device could be utilized to adjust the height of platform 28 above surface 20. It is to be noted that the alternative embodiment is not provided with the full framework shown in FIG. 1, which would include counterweights 40, but framework 32 stops at handrail 34. Center of gravity 46, FIG. 2, substantially above the center-of-curvature 42 of spherical surface 18, is that of only the operator and does not include the simulator structure.

An alternative embodiment of the invention would utilize a structure simulator to that of either FIGS. 1 or 2 but weights 58 would be attached to the surface of support 16 to provide a more stable but active device. It is only necessary that weights 58 be located below center-of-curvature 42. The greater the amount of weight added the greater will be the effort required to rotate the device to thus provide the exerciser or gymnastic equipment.

Referring now to FIG. 3 wherein is shown a diagrammatic analysis of a rocket powered platform at an initial angle, beta, with respect to some external reference 88 such as the horizon and which the operator desires to return to a level attitude such that beta equals zero degrees. To accomplish this, kinesthetic control calls for the operator to maintain his center-of-gravity above the center of the platform with respect to external reference 88, the horizon. The reactive force on the man is equal to the mass of the man times the acceleration created by the rocket,  $F = ma$ . The control moment created by this reaction is equal to the reactive force, times the moment arm,  $M = Fl \sin \delta$ . In this expression  $F$  is the reactive force,  $l$  the distance from the center of the platform to the operator's center-of-gravity, and  $\delta$  is the kinesthetic control angle, see FIG. 3. If  $a$  in the force equation,  $F = ma$ , is equal to the acceleration of gravity then  $F = W$ , the weight of the man, and the moment equation reduces to  $M = W l \sin \delta$ .

As seen in FIG. 4, the platform simulator is at an initial angle, beta, with respect to external reference 88, the horizon, and it is desired to return the platform to a level attitude, beta equals zero degrees. To accomplish this reorientation, kinesthetic control calls for the operator to stand erect, moving his center-of-gravity 46 from point A to point B through the control angle  $\delta$ . Simulator 10 is mass-balanced by weights 40, see FIG. 1, which put its center-of-mass at center-of-curvature 42. Therefore, no gravity moments are created on simulator 10 as a result of tilting; only inertia moments are present. Gravity moments are put in only by the operator and are equal to his weight  $W$  times the horizontal distance  $b$  between the vertical action line of his weight passing through center-of-gravity 46 at point B and the line-of-action of the floor reaction  $F$  which is directly below point A. From the right angle triangle with base  $b$ , hypotenuse  $l$  and acute angle beta, the following relation may be written:  $b = l \sin \beta$ , see FIG. 4. Since  $\delta$  is equal to  $\beta$ , the expression may be written as  $b = l \sin \delta$ . The righting moment, therefore, is:

$$M = W l \sin \delta$$

which is exactly the same as for the rocket powered platform, whatever the value of  $\delta$ . Thus the kinesthetically induced reactions of an operator of the simulator are equivalent to those of an operator of an actual

rocket powered platform, and both the actual platform and the simulator have the same control "feel".

Referring now to FIG. 5 wherein framework 30 of simulator 10, as shown in FIG. 1, is shown to have outwardly extending horizontal conduits 62 which convey air pressure from a source, not shown, to nozzles 60 for release to establish a thrust,  $T$ , which is always aligned with the axis of simulator 10 such that a horizontal accelerating force equal to  $T \sin \beta$  is provided to give horizontal translation in any direction. Platform 28 is shown as mounted on four air pads 74 which utilize the pneumatic pressure from four motorized blowers 76 to support the entire simulator on a smooth level floor permitting relatively frictionless translation in a plane and a total of five degrees of motion freedom. The simulator in this configuration has two degrees of translational freedom across a floor or the like as well as three degrees of rotational freedom including rotation about a vertical axis and freedom to tilt in all directions from the vertical. The device as shown in FIG. 5 relates only to a translational device and not to a nontranslational configuration as shown in FIG. 1 wherein it is critical to have the center-of-gravity and the center-of-curvature at an identical location for zero static stability. Utilization of the translational system of FIG. 5 permits investigation of situations where stabilizing gear, such as gyros, can be located on control simulator 10, as seen in FIG. 2 by providing a combined center-of-gravity with respect to the center-of-curvature. In the translational system investigators are primarily interested in zero stability, but there must be slight static stability, to compensate for the inertia of the dolly, as seen in FIGS. 5 and 6, in the translational embodiment. It is possible to vary the static stability to investigate the capability of an operator to compensate for stabilizing gear on board simulator 10.

More detail of the translational support system is shown in FIG. 6 for providing five degrees of freedom of motion for control simulator 10. In the FIG. 6 embodiment dolly 78 includes enlarged base 70 which has conduit legs 72 attached thereto which extend downwardly to terminate at pads 74. Power supply means, such as squirrel cage motors 76 are attached to the undersurface of enlarged base 70 and provide a source of air pressure which flows through conduit legs to pads 74 to maintain pneumatic support of dolly 78. A source of power supply such as electrical current could be provided by some external source in which case it would be merely necessary to have one electrical conduit, not shown, extending from dolly 78 to the source of the electrical current or a portable supply, such as batteries, not shown, could be mounted on dolly 78.

#### OPERATION

To operate simulator 10 the operator, while standing on platform 28, utilizes whatever body motions are necessary to produce desired platform rotations. In the embodiment of the invention shown in FIG. 1 kinesthetic control simulator 10 is balanced about center-of-curvature 42 of spherical surface 18, by means of counterweights 40 attached to framework 30. Stand-on platform 28 is located with respect to center-of-curvature 42 of spherical surface 18 such that center-of-gravity 44 of the simulator including the weight of the operator standing in the normal upright attitude coincides with center-of-curvature 42. This arrangement provides the

neutral, 'zero,' stability in the simulation device that is also present in a flying platform.

The second embodiment of the instant invention provides a variable stability capability which is of value in demonstrating kinesthetic control to those unacquainted with the flying platform. In the embodiment shown in FIG. 2 the length of columns 56 is increased to produce a decrease in stability of the operator-device combination. In this configuration counterweights 40 are removed from simulator 10. However, columns 56 elevate the center-of-gravity of the simulator to a position at or slightly above the center-of-gravity 42. Location of center-of-curvature 42 approximately at the surface of stand-on platform 28 establishes a nearly neutral or slightly negative stability for the combination depending upon the stature and weight of the operator.

A further alternative embodiment of the instant invention involves the use of a lightweight construction in conjunction with a rugged maximum tilt ring 50 which would make simulator 10 useful as an item of playground equipment. Furthermore, the elimination of columns 22 and 56 and the addition of weights 58 to spherical surface 18 would increase the positive stability of the device and adapt it for use as an item of gymnasium equipment. The two variations of this alternative embodiment of the instant invention provide a potential use as body building exercisers for arm and leg muscles.

The embodiment of the invention as shown in FIGS. 5 and 6 relates to a translational embodiment having five degrees of freedom of motion available due to the suspension of kinesthetic control simulator 10 above the surface upon which it would normally operate. Thus, in FIG. 5 is shown a construction having four air pads which would utilize power sources 76, for example four electric motors or gasoline engines, for providing a pneumatic source of supply for an air cushion to maintain simulator 10 in a position for complete freedom in the various attitudes. Nozzles 60 provide downward thrust and also permit the operator to have translational control.

The embodiment shown in FIG. 6 operates similar to that of FIG. 5; however, a plurality of pads 74 are utilized for support for dolly 78 which has enlarged base 70 for receiving simulator 10 with base 12 thereon.

Thus it is seen that the instant invention has advantages over previously known devices in simplicity and realistic simulation of a flying platform. It is to be noted that the novel simulator disclosed herein can be produced inexpensively and requires little or no maintenance. It is possible to alter the construction from the

embodiment shown in FIG. 1 to that of FIGS. 2, 5 or 6 in a very minimal time period. The device, furthermore, requires no external power source and because it utilizes only the operator for any type of power, it is available on demand. Moreover, the instant simulator provides a readily available and accessible device for observation of many problems of scientific interest such as high moment of inertia configuration, instrument handling qualities and multipassenger-carrying capability. For example, the novel simulator is able to assist in investigations to determine the passenger-carrying capability of a lunar flyer. It has been established that the operator can carry either one or two passengers without difficulty with the construction of the instant invention. Moreover, a control simulator having five degrees of freedom of motion is instantly available simply by mounting the simulator structure on a dolly such as shown in FIGS. 5 and 6.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A kinesthetic control simulator comprising:  
support means having a spherical lower surface;  
base means for support of said support means;  
a platform mounted in spaced relation to said support means for supporting an operator;  
framework means extending upwardly from said platform; and

means for vertically positioning the center of gravity of the simulator and an operator above, below and corresponding to the center of rotation of said spherical lower surface wherein said means for vertically positioning includes column means for spacing said platform from said support means and for vertically positioning the center of gravity of the simulator and an operator relative to the center of rotation of said spherical lower surface whereby the simulator may simulate a stable, unstable and neutrally stable flying platform.

2. The simulator of claim 1 wherein said means for vertically positioning includes a first removably counterweight means attached to said framework means and a second removably counterweight means attached to said support means, said first and second counterweight means for vertically positioning the center of gravity of the simulator and an operator relative to the center of curvature of said spherical lower surface.

3. The simulator of claim 2 including pneumatic support means for the simulator, whereby five degrees freedom of motion is provided for simulation of a powered, flying platform.

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